1 Description

2

3 Device for protecting electronic modules in a multi-voltage on-

4 board electrical system against short circuits

5

6 The invention relates to a device for protecting electronic

7 modules, in particular modules in electronic control systems,

8 data processing and transmission systems, low-power driver

9 circuits or CAN BUS transceivers, which are generally operated

10 at a supply voltage Vcc = 5V to 10V and are disposed in a

11 control device, in other words ultimately control device

12 connections in a multi-voltage on-board electrical system, for

13 example a 42V/14V vehicle on-board electrical system against

14 short circuits to the highest voltage occurring in said on-

15 board electrical system.

16

17 The ever-increasing energy requirement of new electricity

18 consumers in motor vehicles and the need to reduce fuel

19 consumption, for example by assisting the drive train (stop and

20 go, boost and recovered braking) are driving forces in the move

21 from 14V on-board electrical systems to 42V on-board electrical

22 systems.

23

24 In order to be able to operate electronic modules and

25 components developed for a 14V on-board electrical system,

26 which include the electronic control system and data

27 transmission modules mentioned above, in the 42V on-board

28 electrical system, a 14V/42V on-board electrical system was

29 defined as an interim solution and the description which

30 follows refers to this.

31

32 The biggest obstacle to the continued use of electronic modules

33 and their components developed for the 14V on-board electrical

1 system – with the low on-board electrical system voltage – in
2 the 42V on-board electrical system – with the high on-board
3 electrical system voltage – is their inability to withstand
4 short circuits, for example to 50V in permanent mode or 60V in
5 transient mode.
6
7 In motor vehicles the lines to the modules mentioned are laid
8 in cable trees. Short circuits (flashovers, arcs) between these
9 lines can result for example due to said lines rubbing
10 together. The speed of the change in voltage in the event of a
11 short circuit from for example 5V or 14V to 42V is extremely
12 rapid, a matter of a few nanoseconds.
13
14 Protective circuits are therefore required, which can also be
15 used later in the 42V on-board electrical system.
16
17 Although previously a permanent ability to withstand short
18 circuits to 14V to 18V, depending on the customers'
19 requirements, and a transient ability to withstand short
20 circuits to 32V to 36V was adequate, in the 42V on-board
21 electrical system, as mentioned above, it is necessary to
22 withstand voltages for example to 50V in permanent mode and 60V
23 in transient mode.
24
25 A typical protective circuit according to the prior art in a
26 14V on-board electrical system for example for a
27 microcontroller µC disposed in a control device ST is shown in
28 Figure 2. The input E of the microcontroller µC is for example
29 shown as the input of an analogue-digital converter (ADC) (not
30 shown), to which the output signal of a sensor Se comprising a
31 changing resistance is supplied via a line L, said output
32 signal being digitised and further processed in the analogue-
33 digital converter (ADC) indicated by an arrow.

1

2 A stable supply voltage Vcc, generally Vcc = 5V, is supplied to

3 the microcontroller µC by means of a regulator (not shown) in

4 the control device ST.

5

6 The input E is assigned a protective structure integrated as

7 standard in the microcontroller µC and protecting against

8 electrostatic discharges, comprising a resistor R5 downstream

9 from the input E and two diodes D3 and D4, with the diode D3

10 disposed between the resistor R5 and the positive pole +Vcc of

11 the supply voltage VCC and conducting current in the direction

12 of the positive pole +Vcc, and with the diode D4 disposed

13 between the negative pole −Vcc of the supply voltage Vcc

14 (ground potential GND of the control device ST) and the

15 resistor R5 and conducting current in the direction of the

16 resistor R5.

17

18 Two resistors R6 and R7, which are parallel to the diodes D3

19 and D4, represent parasitic leakage resistances. Because of the

20 high temperatures of > 100°C occurring during operation and the

21 temperature dependency of the leakage currents in

22 semiconductors these values can reach up to 1µA. This

23 corresponds to a leakage resistance R6, R7 of approximately

24 2.5MΩ each.

25

26 Disposed between the sensor S and the positive pole +Vcc in the

27 control device but outside the microcontroller µC is a resistor

28 R1, which together with the internal resistance Rsens of the

29 sensor S forms a voltage divider, which is supplied with the

30 supply voltage Vcc.

31

32 Disposed between the pick-off of this voltage divider and the

33 input E of the microcontroller µC is a protective resistor R2.

1   The divider voltage of the voltage divider R1/Rsens is present
2   at the input E of the microcontroller µC, across the protective
3   resistor R2. It is a measure of the internal resistance of the
4   sensor.
5
6   The protective resistor R2 should be dimensioned such that
7   - the error caused by the parasitic leakage resistances R6, R7
8   of the input protection circuit is small and
9   - with an external maximum voltage in the event of an error Vin
10 = Vbat, the current flowing through the diode D3 is limited to
11 an acceptable level, for example < 5mA.
12 In the 14V on-board electrical system it is however no longer
13 possible to satisfy both requirements in the event of an
14 increase from 14V to 42V:
15 - if the protective resistor R2 is so large that the current
16 flowing through the diode D3 remains acceptably small, the
17 voltage errors caused by the leakage currents flowing through
18 the resistors R6, R7 become unacceptably large;
19 - if the value of the protective resistor R2 is left unchanged,
20 the current that is now increased threefold (due to 14V -> 42V)
21 will damage or destroy the input structure of the
22 microcontroller µC in the event of a short circuit to 42V.
23
24 This known protective circuit is therefore not protected
25 against a short circuit to 42V.
26
27 An overvoltage protection circuit, in particular for the inputs
28 of integrated circuits, is known from DE 197 28 783 A1, with an
29 overvoltage identification device, which, if an overvoltage
30 occurs on the input line, activates a transistor connected in
31 series to this input line and shown as a MOS field effect
32 transistor, which then brings about a high-resistance break in
33 this input line. In normal conditions this MOS field effect

1 transistor (hereafter referred to as MOSFET) represents a low-
2 resistance line in both directions.

3

4 The transistor is located with its drain source path in the
5 line to be protected. Between the source connection and the
6 gate connection of said transistor is a Zener diode, which
7 limits the gate source voltage to a predefined value and
8 between the gate connection and the positive pole of the on-
9 board electrical system voltage is a gate resistor.

10

11 This circuit is based on the principle of identifying an
12 overvoltage with subsequent disconnection of the in-phase
13 transistor. However in principle voltage identification is
14 associated with a delay time.

15

16 If an overvoltage now occurs in the form of a rapid voltage
17 change (e.g. short circuit due to voltage flashover to the
18 higher on-board electrical system voltage 42V), the voltage
19 suddenly increases at the nodes to be protected until the end
20 of the delay time plus the disconnection time of the in-phase
21 transistor. The speed of the voltage change in the event of a
22 short circuit to 42V is however extremely rapid, as mentioned
23 above.

24

25 With such rapid voltage changes, disconnection of the in-phase
26 transistor – due to the delays associated in principle – takes
27 place only after the high voltage is already present at the
28 nodes to be protected. This is also described in the said DE
29 197 28 783 A1, in that "only small switching peaks occur
30 respectively at the start and end of each of the overvoltage
31 pulses" (column 4, lines 62 to 65).

32

1 A circuit operating according to the same principle is known

2 from DE 3425235 C1.

3

4 Such rapid voltage changes cause the circuits described in the

5 two documents to fail in principle and they are therefore

6 unsuitable for use in the twin-voltage on-board electrical

7 system or in the single voltage on-board electrical system with

8 the higher on-board electrical system voltage,

9

10 The switching process can – depending on the design – take

11 between several 100 ns and several μs. Destruction of the

12 components to be protected cannot be excluded.

13

14 The object of the invention is to create a simple device for

15 protecting electronic modules used in a 14V on-board electrical

16 system and disposed in a control device, i.e. therefore the

17 control device inputs and outputs, such that these modules can

18 also be protected reliably against short circuits occurring in

19 a 42V on-board electrical system.

20

21 This object is achieved according to the invention by a device

22 according to the features of claim 1.

23

24 Advantageous developments of the invention will emerge from the

25 subclaims.

26

27 Exemplary embodiments of the invention are described in more

28 detail below with reference to a schematic drawing, in which:

29

30 Figure 1 shows the circuit of a claimed device for protecting

31 electronic modules used in the 14V on-board electrical system

32 against short circuits in a 42V on-board electrical system,

1 Figure 2 shows a known protective circuit for an input of a
2 microcontroller in a 14V on-board electrical system,
3 Figure 3 shows an exemplary embodiment of the claimed
4 protective circuit for a low-power driver circuit and
5 Figure 4 shows an exemplary embodiment of the claimed
6 protective circuit for a CAN bus transceiver.
7
8 The invention does not use overvoltage identification devices
9 with subsequent disconnection of the in-phase transistor,
10 rather it is based on the principle of limiting the current in
11 the in-phase transistor using its cut-off voltage.
12
13 Figure 1 shows the circuit of a claimed protective circuit Ss
14 disposed in a control device ST for a microcontroller μC known
15 from Figure 2 against short circuits in a 42V on-board
16 electrical system, said circuit being inserted between the
17 protective resistor R2 and the line L (the control device
18 connection A). In addition to the circuit shown in Figure 2,
19 Figure 1 also shows the 12V battery Bat1 of the on-board
20 electrical system with the low on-board voltage present in the
21 14V/42V on-board electrical system, while the voltage source of
22 the on-board electrical system with the high on-board voltage
23 is not shown.
24
25 The voltage arrow also shown in Figure 1 indicates the voltage
26 Vin of a sensor Se, which can also be the short-circuit voltage
27 to the 42V on-board electrical system with maximum 60V. This
28 voltage Vin forms the input voltage for the control device ST,
29 the value of which is transmitted to the control device ST from
30 the sensor Se via the line L.
31
32 The protective circuit Ss comprises a circuit set up around a
33 transistor T1, as known from DE 197 28 783 A1. In the case of

1   positive input voltages, this transistor T1 is preferably an N-
2   channel low-power MOSFET (Field Effect Transistor), the drain
3   connection D of which is connected via the control device
4   connection A (the line L) to the sensor Se and the source
5   connection S of which is connected to the protective resistor
6   R2.
7
8   Disposed between the gate connection G of the transistor T1 and
9   the positive pole +Vbat1 of the 12V battery Bat1 in the known
10 manner is the gate resistor Rv and disposed between the gate
11 connection G and the source connection S of the transistor T1
12 is a Zener diode operating as a limiter diode D1, the breakdown
13 voltage Vz of which is selected as for example Vz = 18V, such
14 that it is not conductive in normal operation (Vz > Vbat1) but
15 is conductive just before the maximum permitted gate source
16 voltage Vgs of the transistor T1 is reached, e.g. Vgs = 20V.
17
18 According to the invention a diode D2 is connected parallel to
19 the gate resistor Rv, said diode conducting current in the
20 direction from the gateway connection G to the positive pole
21 +Vbat1 of the battery Bat1.
22
23 This diode D2 limits the gate voltage Vg of the transistor T1
24 to a value Vg = Vbat1 + Vd, i.e. to a value of the sum of the
25 low on-board electrical system voltage Vbat1 plus the
26 conducting state voltage Vd of the diode D2.
27
28 In the case of negative input voltages, the transistor T1 would
29 have to be a P-channel MOSFET, with all voltages, even the
30 processor voltage supply, then having to be reversed. A MOSFET
31 is thus advantageous, because it does not require control
32 current at the operating point. In the case of bipolar
33 transistors, with which the circuit would in principle also

1   function, the base current could impede the measuring function
2   as an additional error current. It is assumed below that the
3   transistor T1 is an N-channel MOSFET and the input voltages are
4   positive.
5
6   In the signal path from the sensor Se to the input E of the
7   microcontroller are just the low-resistance protective resistor
8   R2 and the comparatively low saturation resistance of the
9   transistor T1, for example 5Ω. The sensor signal is thereby
10 only influenced to a minimal degree.
11
12 In normal operation 0V < Vin < Vcc the transistor T1 is
13 conductive, as its gate voltage determined across the gate
14 resistor Rv is 14V and the gate source voltage Vgs at the
15 transistor T1 is significantly greater than its threshold
16 voltage Vth (for example Vth = 3V).
17
18 Investigation of errors occurring:
19
20   a) in the event of a short circuit to ground potential GND
21   (Vin = 0V), the voltage at the input E is also 0V and the
22   protective circuit Ss operates normally.
23   b) in the event of a short circuit to 14V (Vbat1) active at
24   the device connection A, the source voltage Vs of the
25   transistor T1 increases to a value Vs = Vbat1 – Vth, in
26   other words to a value Vs < Vbat1. The transistor T1 is
27   now in the cut-off range. The current through the diode
28   D3 is limited by the protective resistor R2 to a
29   predefined permitted value.
30   c) in the event of negative transient voltages (for example
31   ISO test pulses) active at the device connection A, the
32   transistor T1 becomes conductive, with its gate source
33   voltage Vgs now being limited by the Zener diode D1. The

1   gate resistor Rv limits the current flow through the

2   Zener diode D1 to a tolerable value. The protective

3   resistor R2 limits the current flow through the diode D4

4   of the protective structure of the microcontroller μC.

5   d) in the event of a short circuit to the 42V on-board

6   electrical system active at the device connection A, the

7   input voltage Vin increases drastically – up to maximum

8   60V. The source voltage Vs of the transistor T1 will

9   increase in the event of a short circuit to 14V to a

10   value Vs = Vbat1 – Vth, i.e. a value Vs < Vbat1. As the

11   transistor T1 is now in the cut-off range, the total

12   voltage difference drops there to the input voltage Vin.

13   The drain source voltage Vds of the transistor T1 becomes

14   Vds = Vin – (Vbat – Vth). The power loss P(T1) resulting

15   at the transistor T1 is thereby determined by the voltage

16   difference Vds and the current I(R2) flowing through the

17   protective resistor R2: P(T1) + Vds*I(R2). The peak value

18   occurring with transient voltages of 60V is < 100mW, the

19   effective value being around 60mW, which can be managed

20   easily using a standard housing for the transistor T1.

21

22 If the input voltage Vin increases to values > Vbat1, the gate

23 source voltage Vgs drops from 14V for example to the threshold

24 voltage Vth, for example Vth = 3V. The gate capacities of the

25 transistor T1 must thereby be transferred. With very rapid

26 transient voltages Vin an increased gate current of Ig > 10mA

27 is required in the short term in the event of a short circuit.

28

29 If this gate current were to flow exclusively across the gate

30 resistor Rv = 10kΩ, it would cause a major voltage drop. The

31 gate voltage would increase to values > 60V for a short time,

32 which would result in a short-term, significantly larger

1 current flow through the diode D3, which could damage or

2 destroy this.

3

4 As the diode D2 parallel to the gate resistor Rv is in this

5 case operated in the current conducting direction, it limits

6 the gate voltage Vg of the transistor T1 to a value Vbat1 + Vd,

7 where Vd is the conducting state voltage of the diode D2.

8

9 The protective circuit thereby carries out its function in the

10 event of an error both in the 14V on-board electrical system

11 (low on-board voltage) and in the 42V on-board electrical

12 system (high on-board voltage) up to the point of rapid

13 transient changes in the input voltage Vin.

14

15 Figure 3 shows an exemplary embodiment of the claimed

16 protective circuit for a low-power driver circuit. A consumer

17 RL supplied by the 14V on-board electrical system, for example

18 a light-emitting diode of a warning light, is switched on and

19 off by means of a switching transistor T2.

20

21 The consumer RL is connected on the one hand to the positive

22 pole of the battery Bat1 and on the other hand via the line L

23 and the switching transistor T2 and a protective resistor Rs to

24 the negative pole GND of the battery Bat1. The switching

25 transistor T2 can generally be part of an integrated circuit

26 configured as a gang switch.

27

28 A short circuit to 42V without the claimed protective circuit

29 would destroy the switching transistor T2.

30

31 To prevent this, the protective circuit Ss known from Figure 1

32 is inserted into this configuration in the control device ST

33 between the transistor T2 and line L, such that the drain

1   connection D of the transistor T1 is connected via the control

2   device connection A and line L to the consumer RL and the

3   source connection S is connected to the switching transistor

4   and such that the point of connection between the gate resistor

5   Rv and the diode D2 is connected to the positive pole of the

6   battery Bat1.

7

8   The function of the protective circuit is the same as already

9   set out in the description of Figure 1.

10

11   Figure 4 finally shows a basic circuit diagram of a CAN bus

12   transceiver C-T disposed in the control device ST with the

13   claimed protective circuit against short circuits to 42V. The

14   transceiver C-T comprises a transmitter TM (transmit module)

15   and a receiver RC (receive module) in the known manner.

16

17   A suitable transceiver C-T for a high-speed version is for

18   example a Philips PCA82C250, the data for which can be found in

19   the data sheet "Philips semiconductors PCA82C250 CAN controller

20   interface, Product specification, 13 January 2000".

21

22   A high-speed CAN BUS generally has two differentially operated

23   lines CAN_HI and CAN_LO, the voltages of which are generally

24   2.5V + 1V and 2.5V - 1V.

25

26   Each of the two bus lines CAN_HI and CAN_LO is equipped with

27   its own

28   - protective circuit Ssa disposed in the control device ST:

29   between the bus line CAN_HI or control device connection A1 and

30   the connection E1 of the transmitter Tm (Ssa) and

31   - protective circuit Ssb disposed in the control device ST:

32   between the bus line CAN_LO or control device connection A2 and

33   the connection E2 of the receiver Rc.

1   In normal operation the protective circuits do not influence
2   the transmitter and receiver functions due to the low
3   saturation resistances of T1a and T1b. The voltage at the
4   transceiver C-T is only limited to a – permitted – value Vbat –
5   Vth in the event of a short circuit to 42V.
6
7   The function of the protective circuits Ssa and Ssb is the same
8   as already set out in the description of Figure 1.
9
10 The claimed protective circuit is significantly simpler than
11 the circuit known from DE 197 28 783 A1 and has significantly
12 fewer components.
13
14 It is suitable
15 - for protecting analogue and digital control device inputs of
16 electronic control system modules and data transmission modules
17 (data interfaces), as well as low-power driver circuits or CAN
18 BUS transceivers, which are operated at a supply voltage of Vcc
19 = 5V to 10V for example and are generally disposed in a control
20 device;
21 - it protects the connections (control device inputs and
22 outputs) reliably, even in the continued presence of high,
23 positive overvoltages; even rapid positive transients such as a
24 short circuit to 60V are not allowed through and are therefore
25 reliably managed and negative transients (e.g. ISO test pulses)
26 are tolerated;
27 - it is intrinsically safe and can be implemented economically
28 and simply with standard components;
29 - its circuit design is suitable for integration in an ASIC,
30 which can also be used later in the 42V single voltage on-board
31 electrical system;
32 - in normal operation it has no significant influence on the
33 accuracy of the capture of measured values;

1 - in normal operation it does not influence the data
2 transmission function.
3
4